(12) UK Patent Application (19) GB (11) 2 337 852 (13) A

(43) Date of A Publication 01.12.1999

(21) Application No 9912300.2

(22) Date of Filing 26.05.1999

(30) Priority Data
(31) 10144120 (32) 26.05.1998 (33) JP

(51) INT CL[6]
H01L 25/065, H05K 1/14

(52) UK CL (Edition Q)
H1K KPX K5A1 K5A4 K5B2 K5B4

(56) Documents Cited
EP 0708484 A1 EP 0540247 A2

(58) Field of Search
UK CL (Edition Q) H1K KPJ KPX KPXB KPXDB KPXMB KRF, H1R RBF
INT CL[6] H01L 23/055 25/04 25/065 25/07, H05K 1/14 3/34
EPOQUE: WPI, EPODOC, PAJ

(71) Applicant(s)
NEC Corporation
(Incorporated in Japan)
7-1 Shiba 5-chome, Minato-ku, Tokyo 108-01, Japan

(72) Inventor(s)
Eiichi Fukiharu

(74) Agent and/or Address for Service
John Orchard & Co
Staple Inn Buildings North, High Holborn, LONDON, WC1V 7PZ, United Kingdom

(54) Abstract Title
Multichip module

(57) A multichip module (MCM) has a first substrate 1 with through holes 6a, 6b and shield electrodes 8 therein. At least one semiconductor device 11 is mounted on, and electrically and mechanically connected to, one major surface of the first substrate. A second substrate 2 is mounted on the other major surface and formed with through holes. At least one filter device 5, preferably a surface acoustic wave filter (SAW filter) or a quartz device, is also mounted on, and electrically and mechanically connected to, the other major surface of the first substrate. The second substrate is electrically connected to the semiconductor device 11 through the through holes. The MCM is capable of enhancing the efficient mounting of devices and promoting easy insulation between the devices, especially in a portable telephone.

FIG. 3

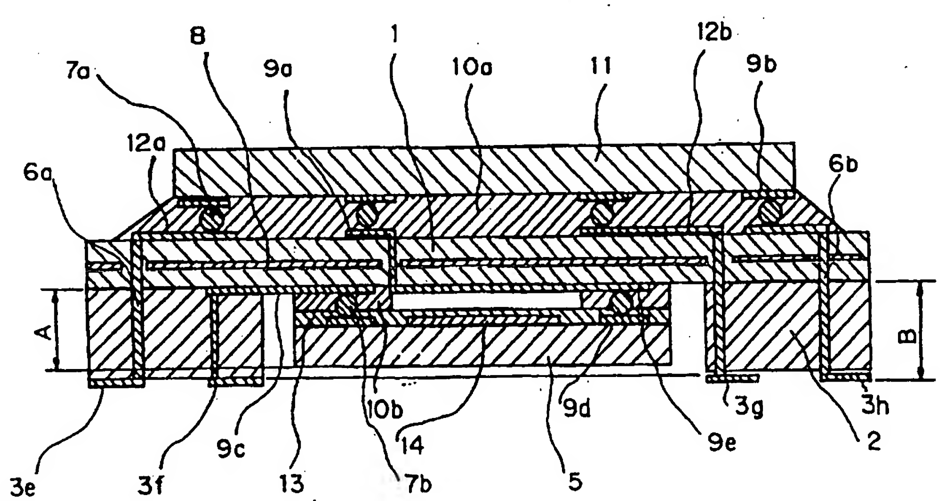

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FIG. 1

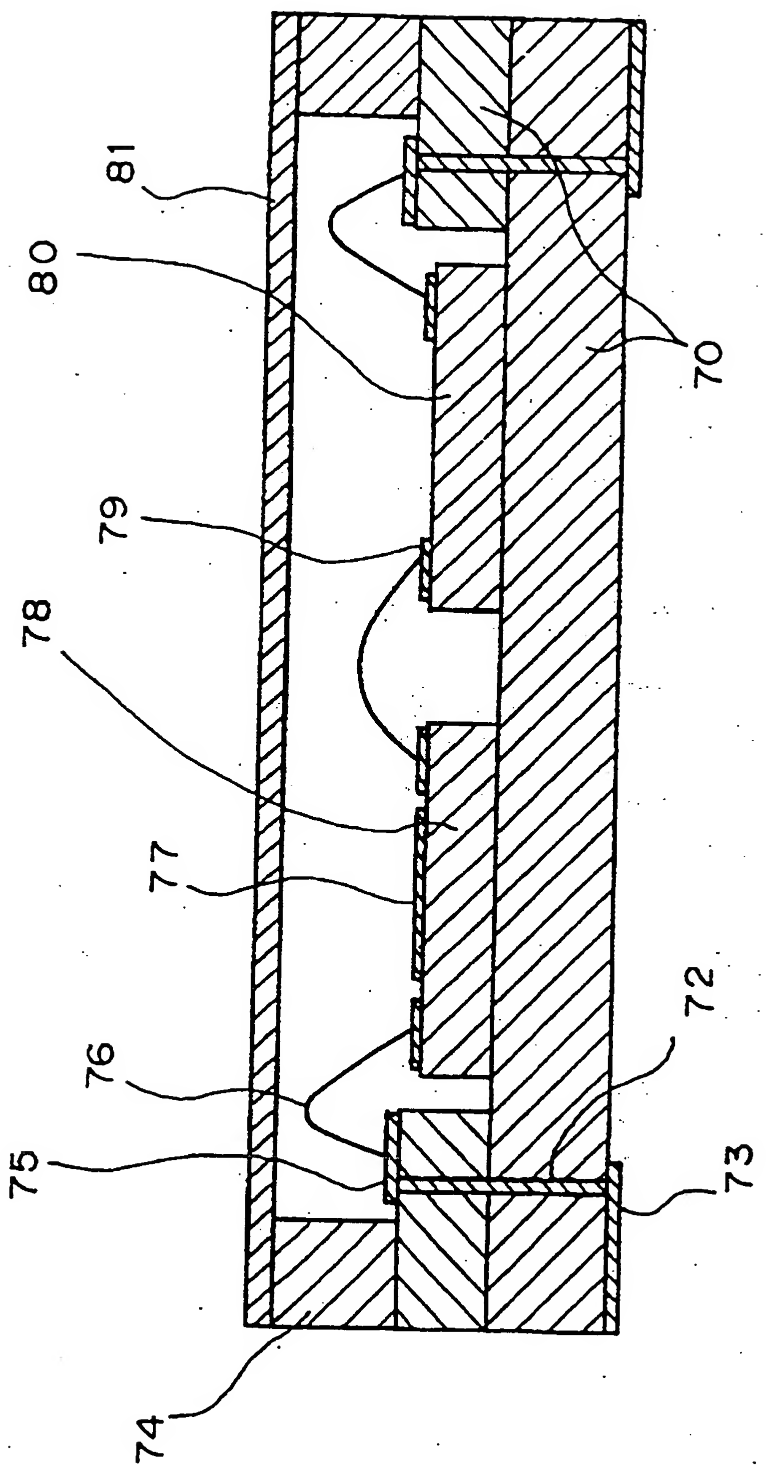


FIG. 2

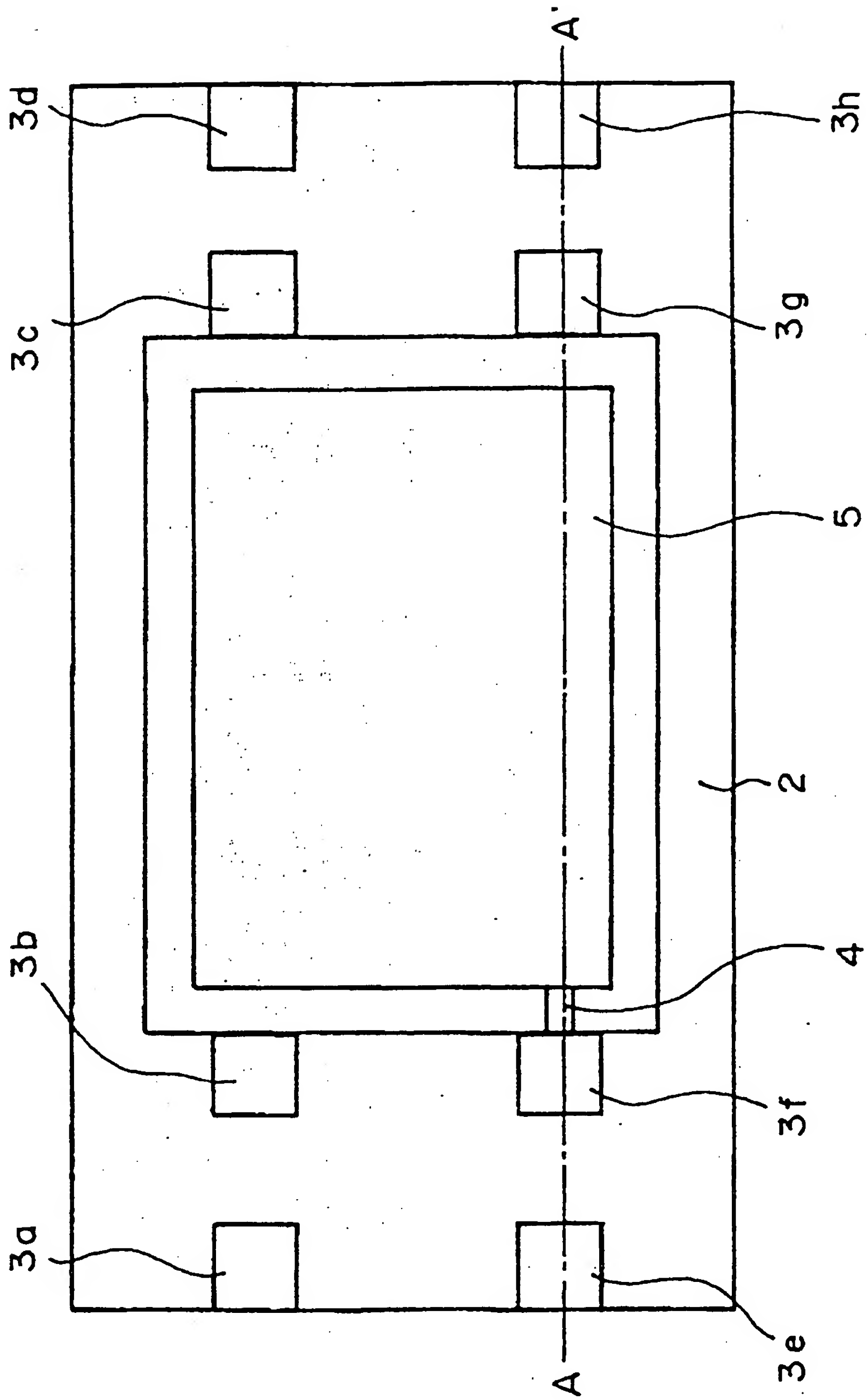


FIG. 3

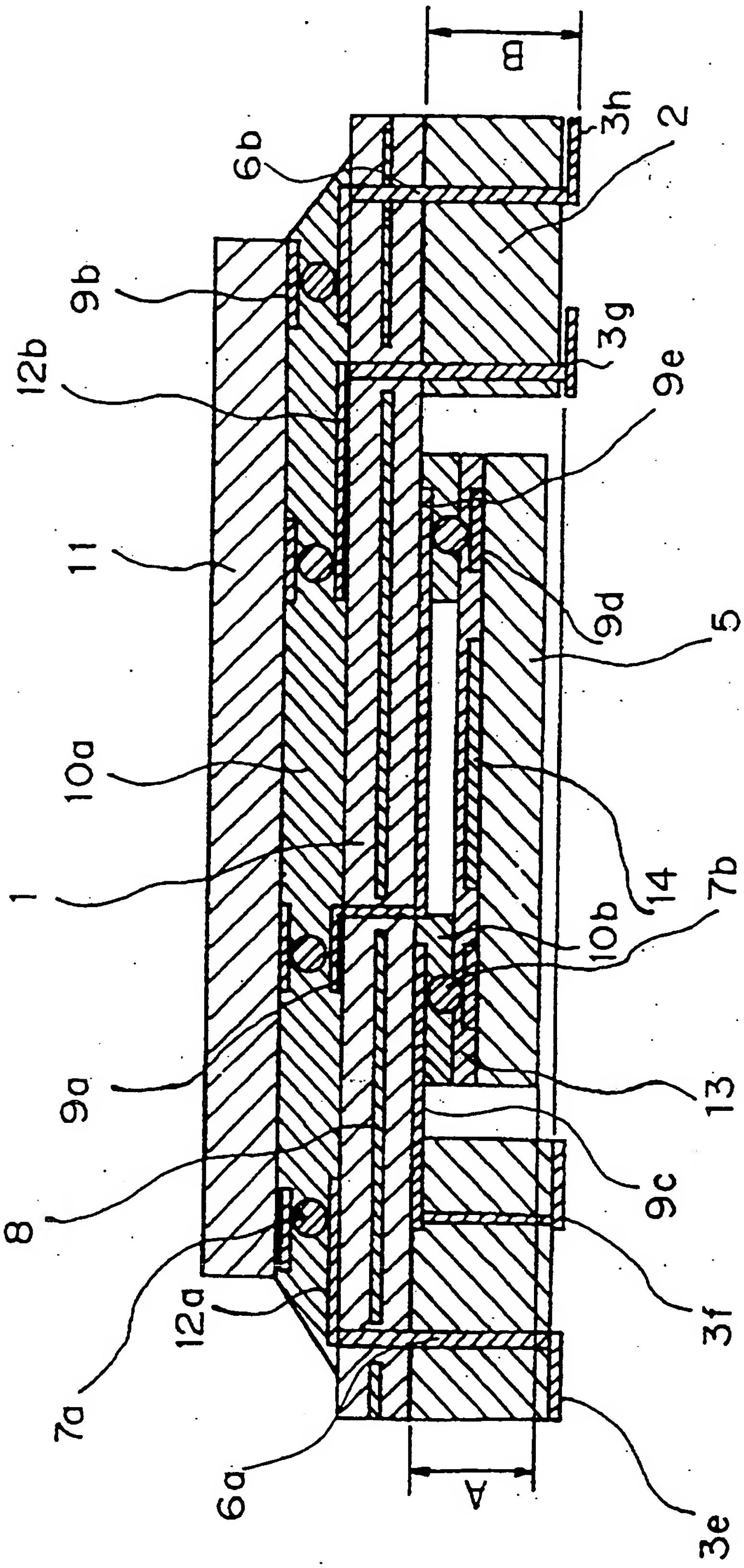

B
3h
2
6b
9b
3g
12b
9e
11
9d
5
10a
14
7b
1
10b
13
9a
9c
8
3f
12a
7a
6a
A
3e

FIG. 4

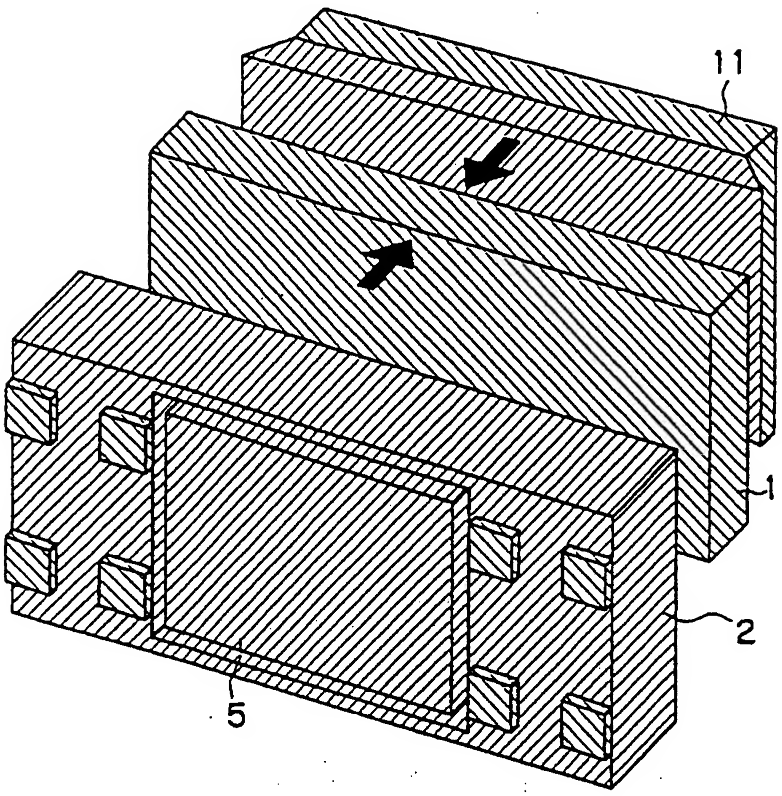


FIG. 5

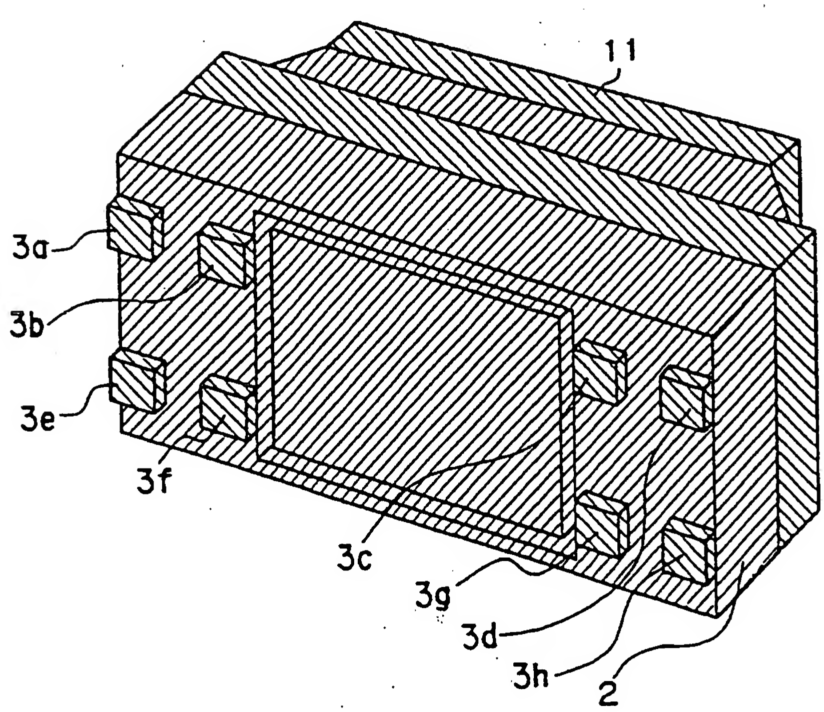


FIG. 6

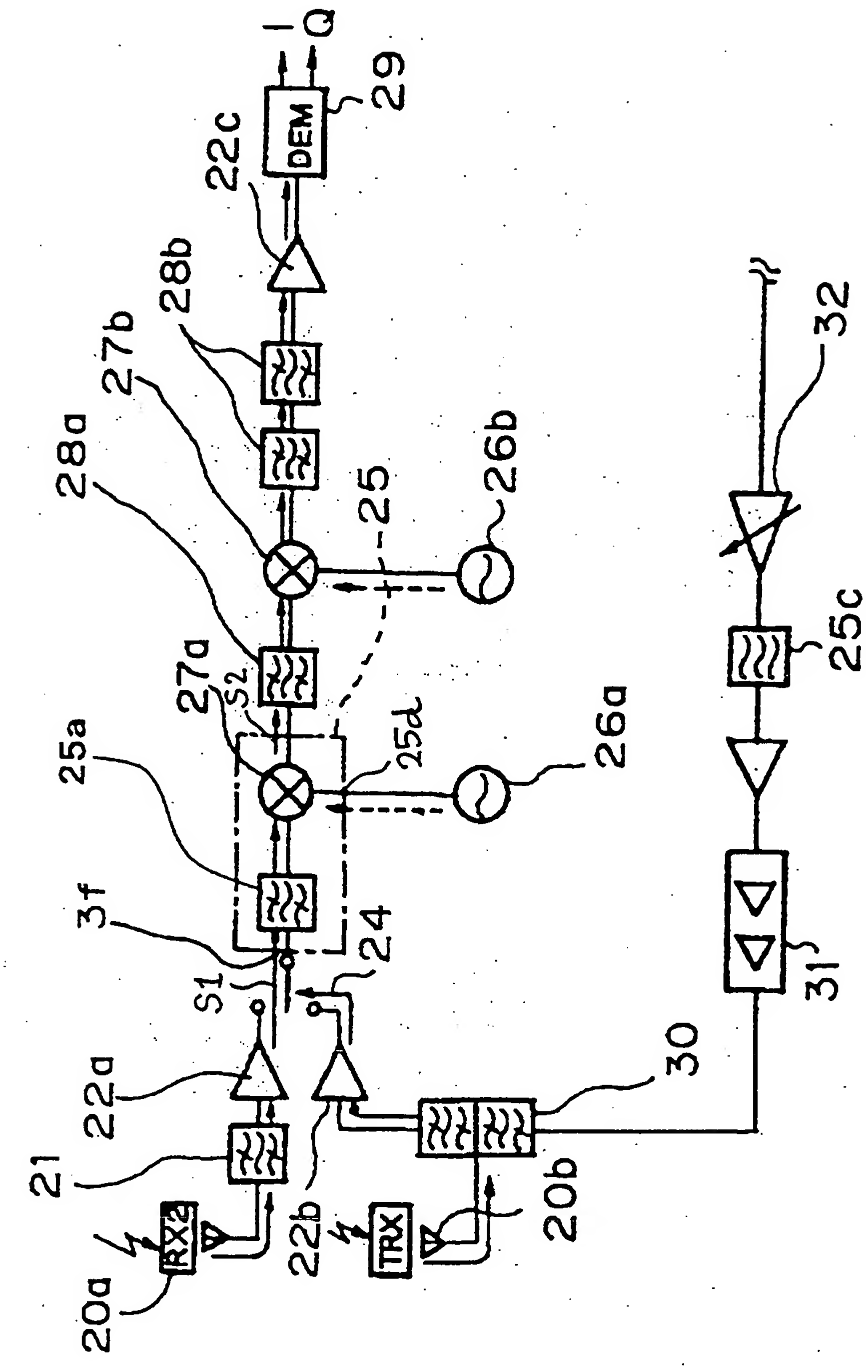

20a
RX2
21
22a
S1
3f
25a
27a
S2
25d
28a
27b
28b
22c
DEM
29
I
Q
25
26a
26b
24
22b
TRX
20b
30
31
25c
32

FIG. 7

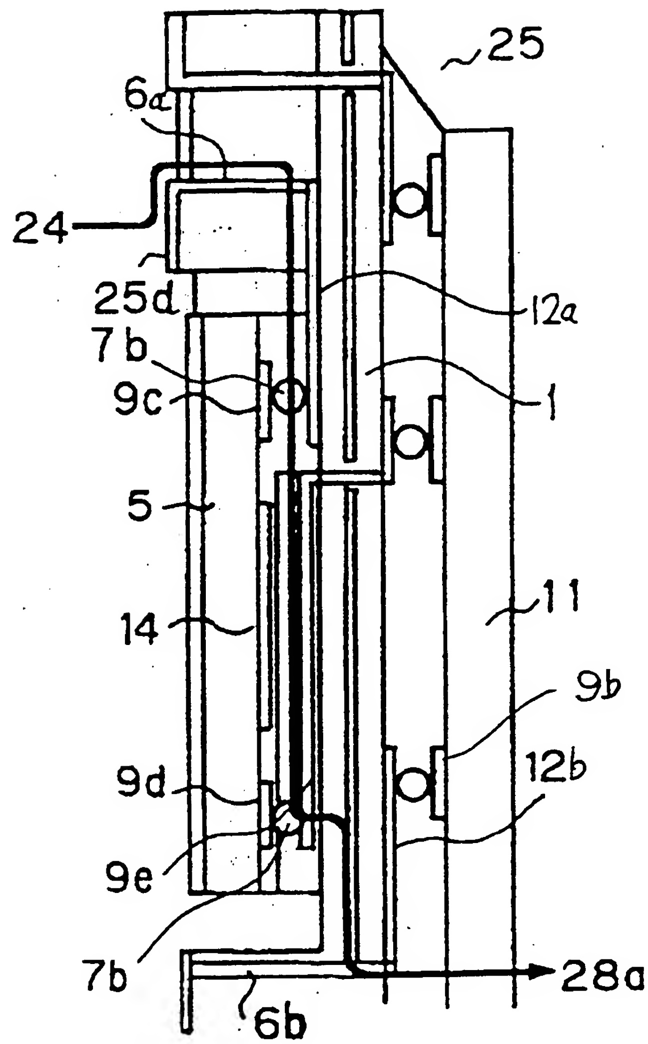


FIG. 8

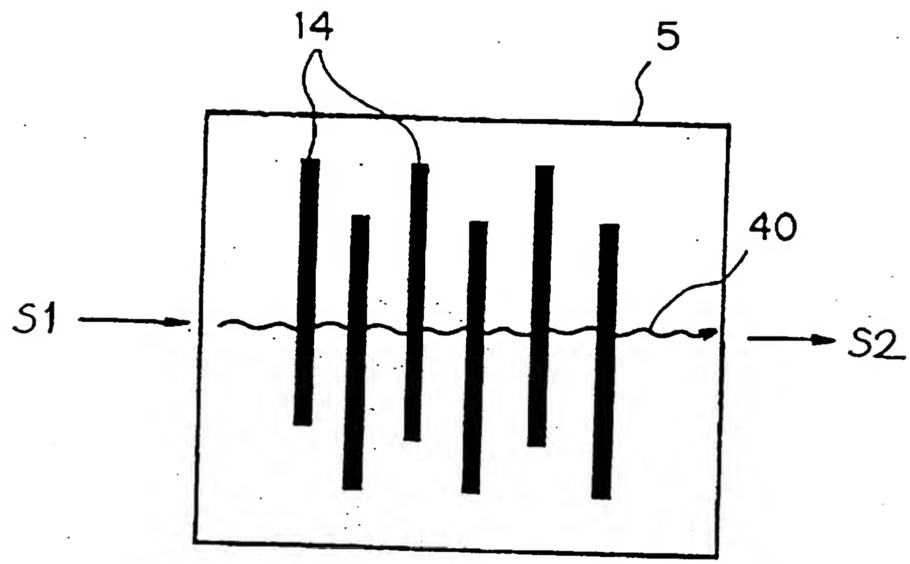


FIG. 9

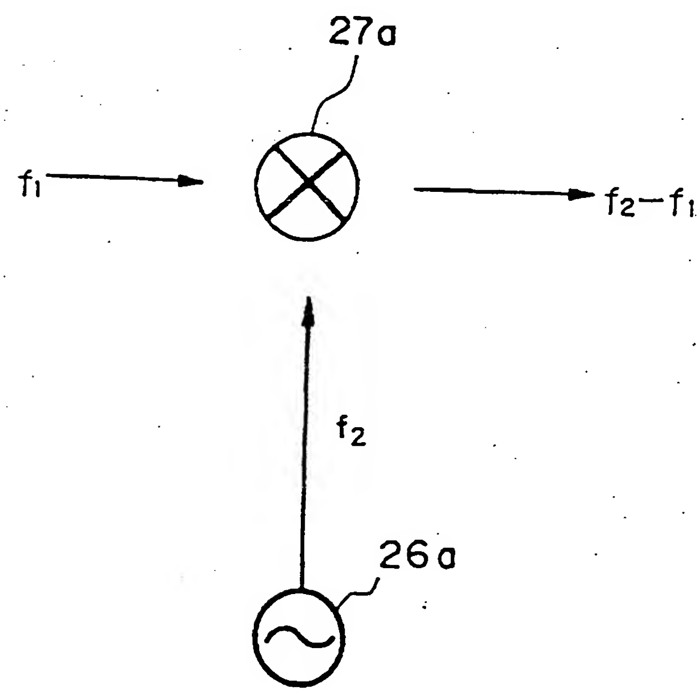
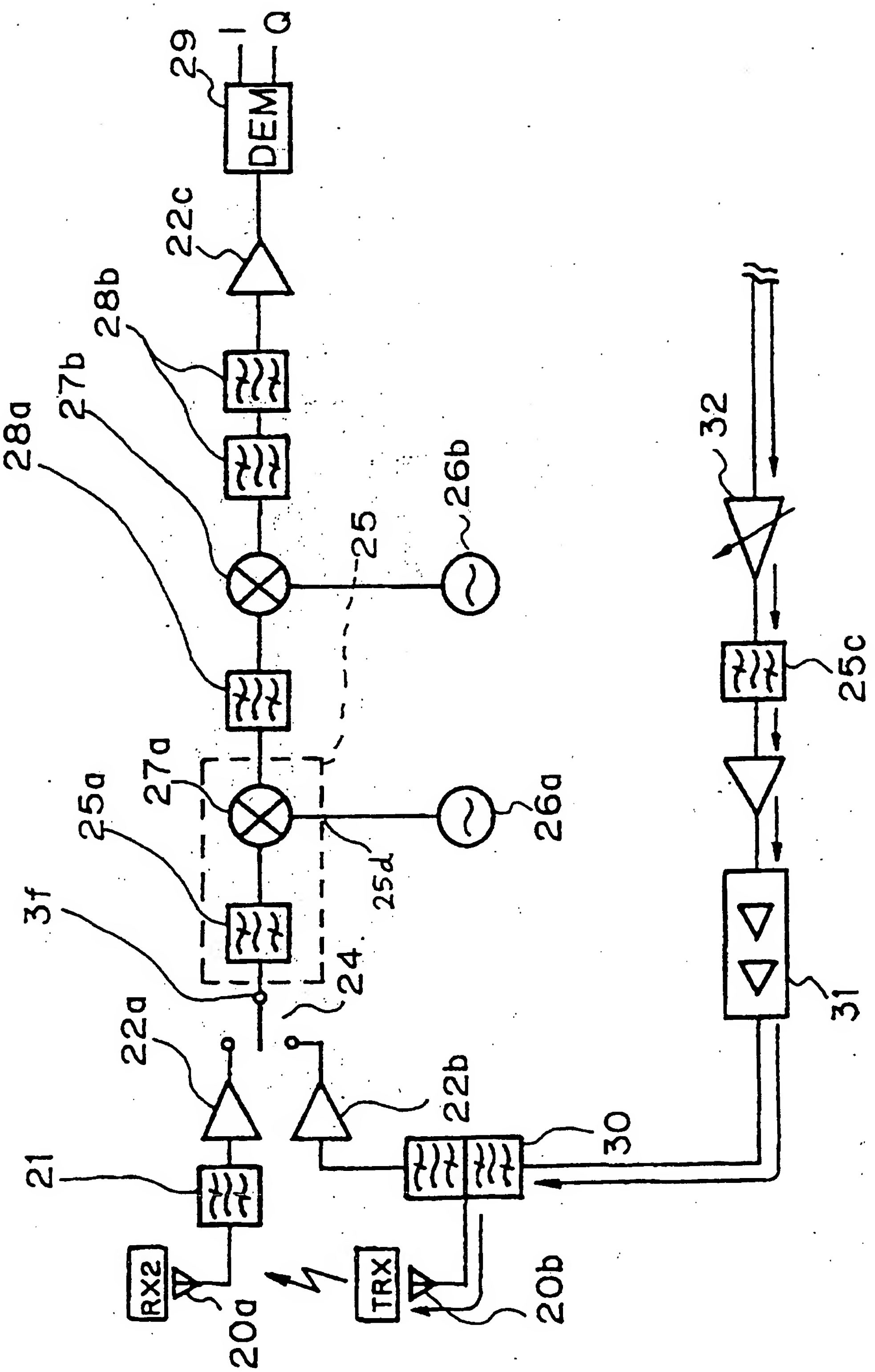


FIG. 10



29
DEM
I
Q
22c
28b
27b
28a
26b
25
27a
25a
3f
24
25d
26a
22a
21
22b
30
RX2
TRX
20a
20b
25c
31
32

FIG. 11

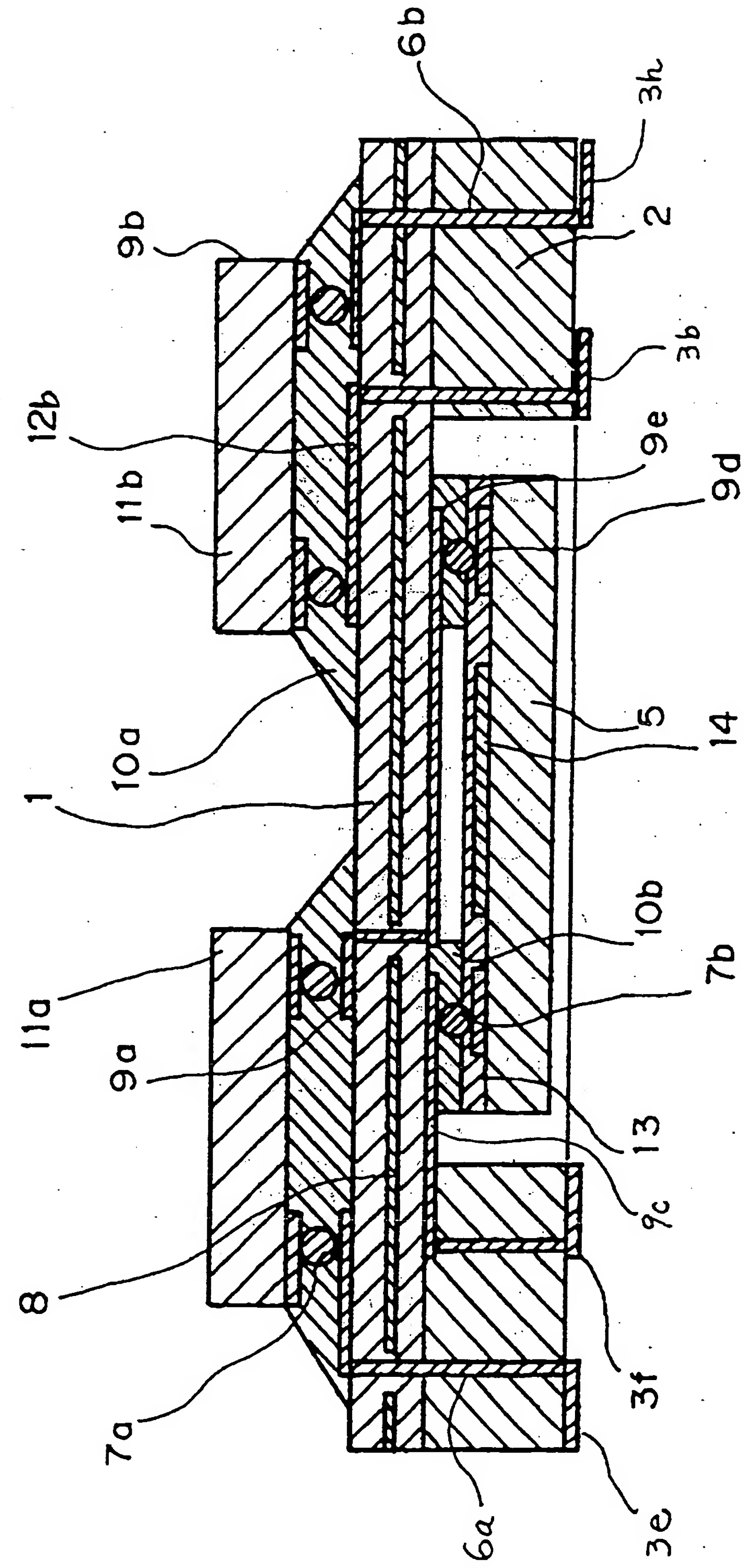
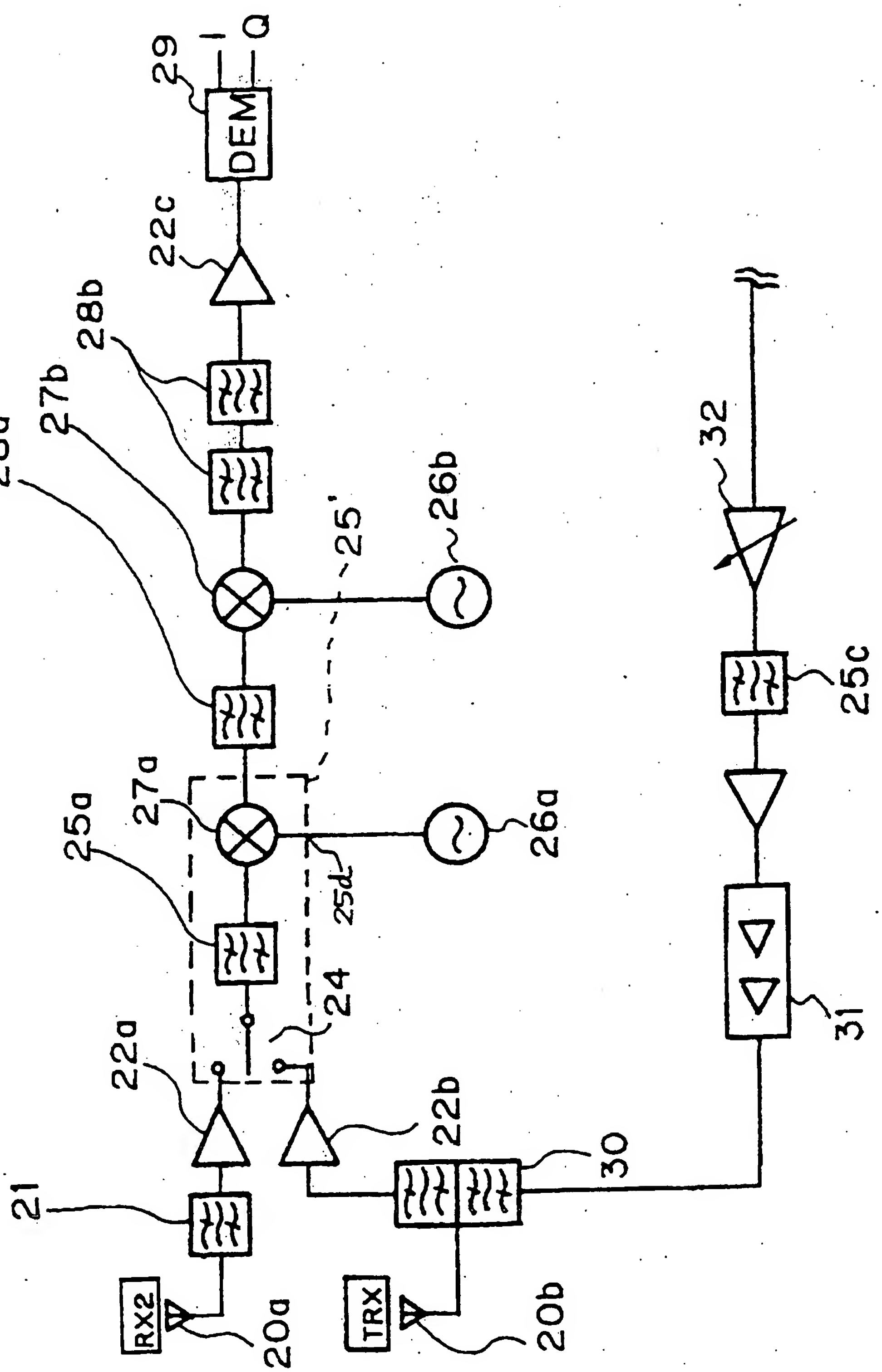


FIG. 12



RX2
20a
21
22a
TRX
20b
22b
30
24
25a
25d
27a
26a
28a
27b
25'
26b
28b
22c
29
DEM
I
Q
31
25c
32

FIG. 13

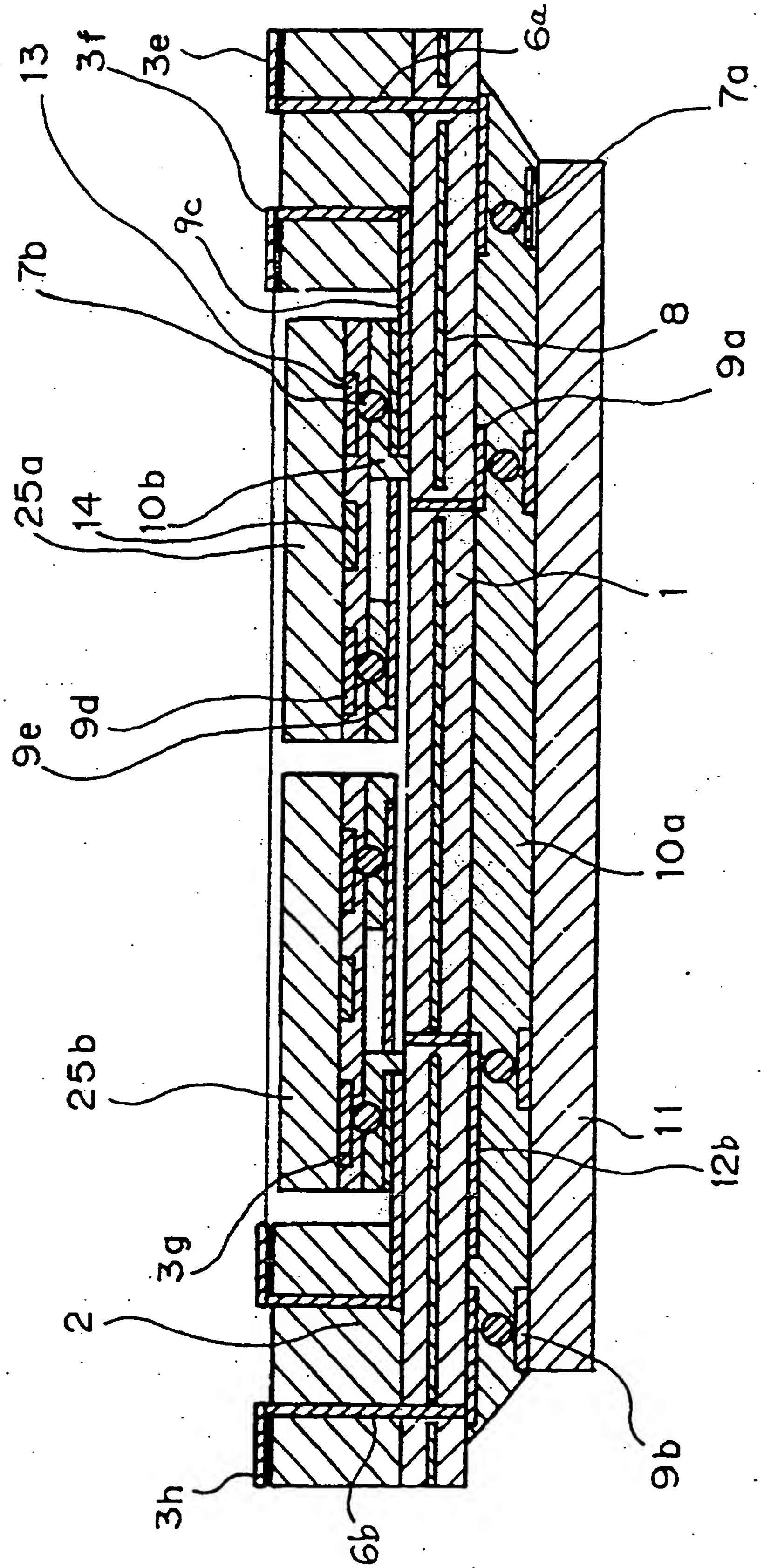

13
3f
3e
6a
7a
7b
9c
8
9a
25a
14
10b
1
9d
9e
10a
25b
11
12b
3g
2
9b
3h
6b

FIG. 14

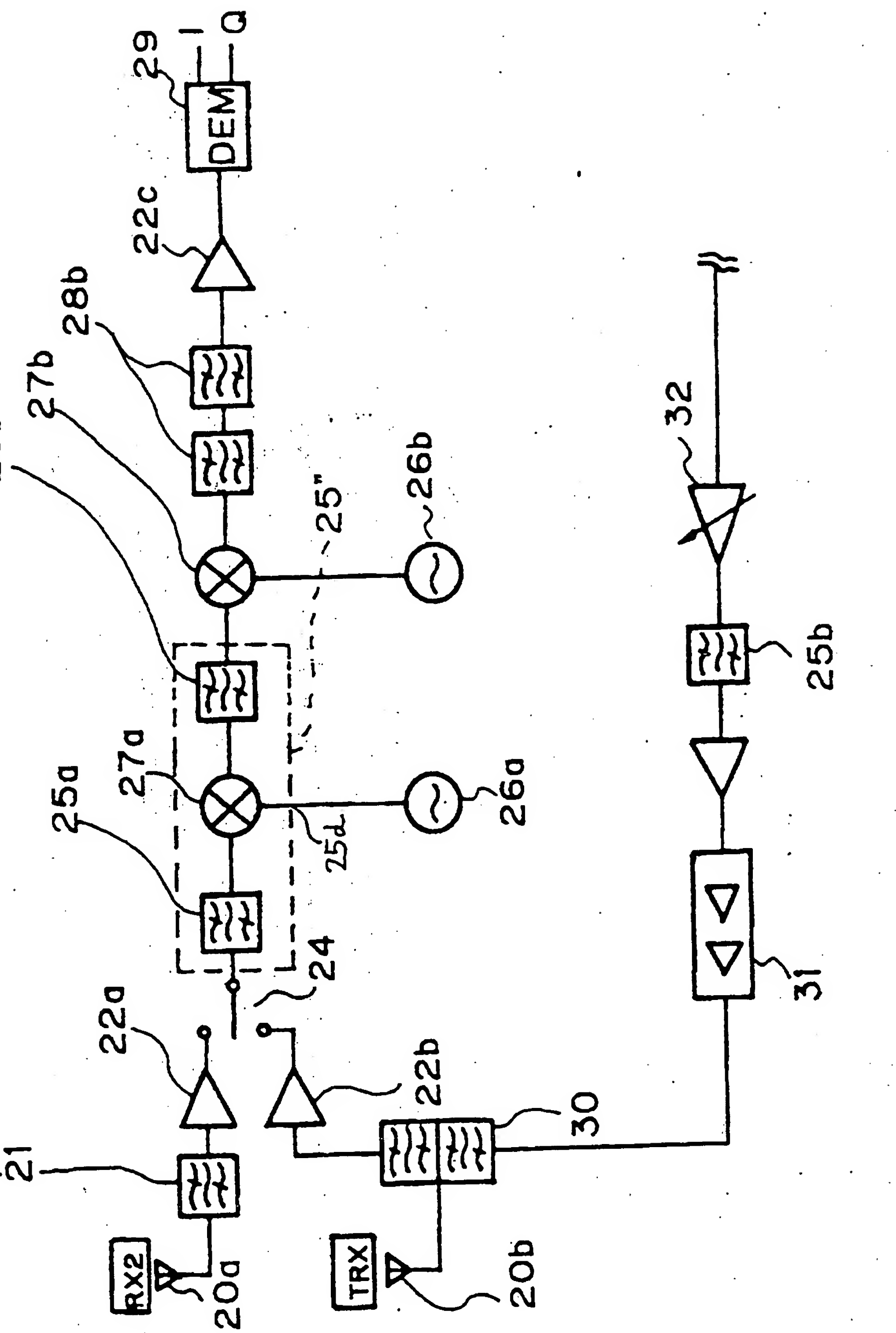

RX2
20a
21
22a
TRX
20b
30
22b
24
25a
27a
25d
26a
25"
25b
27b
26b
28b
22c
DEM
29
I
Q
31
25b
32

FIG. 15

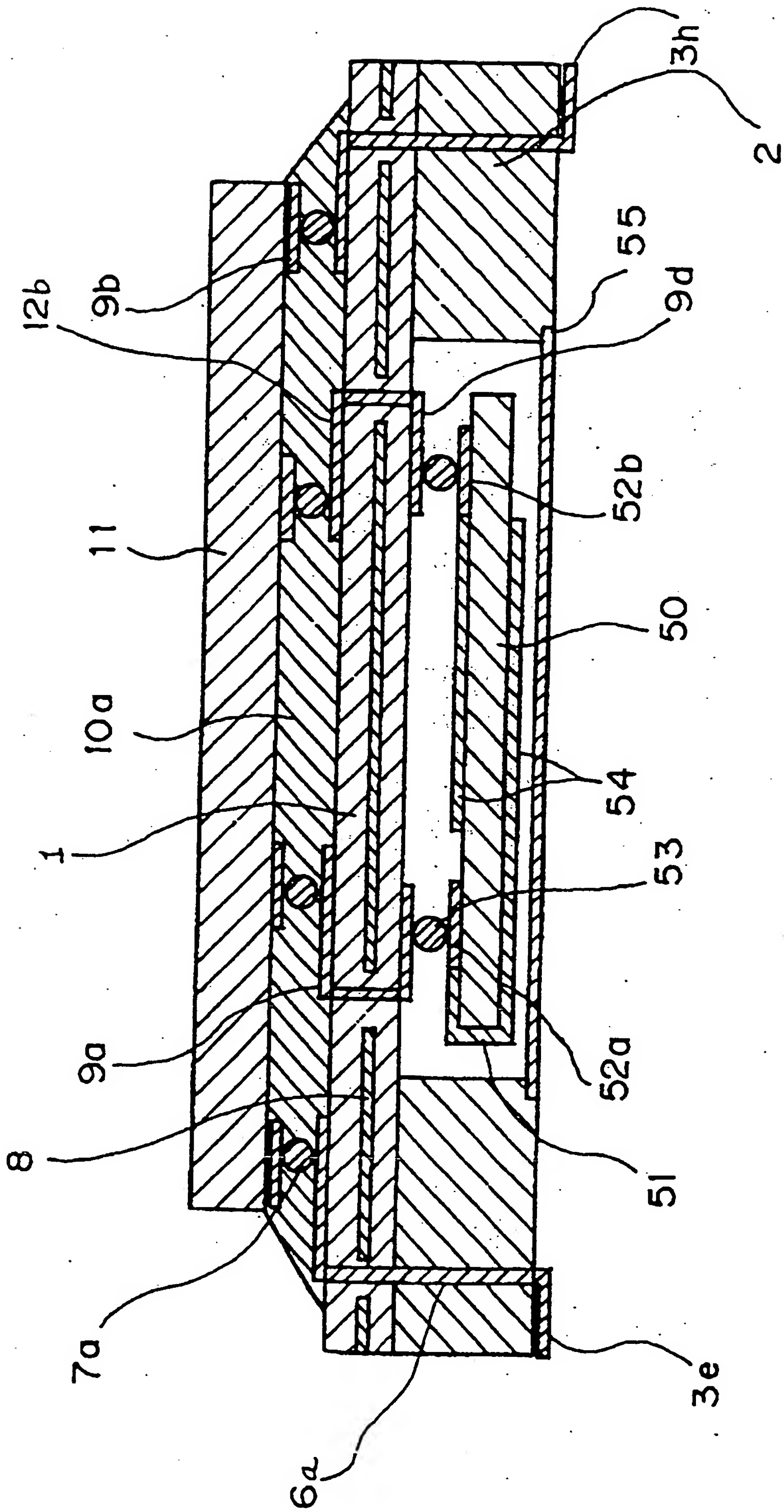
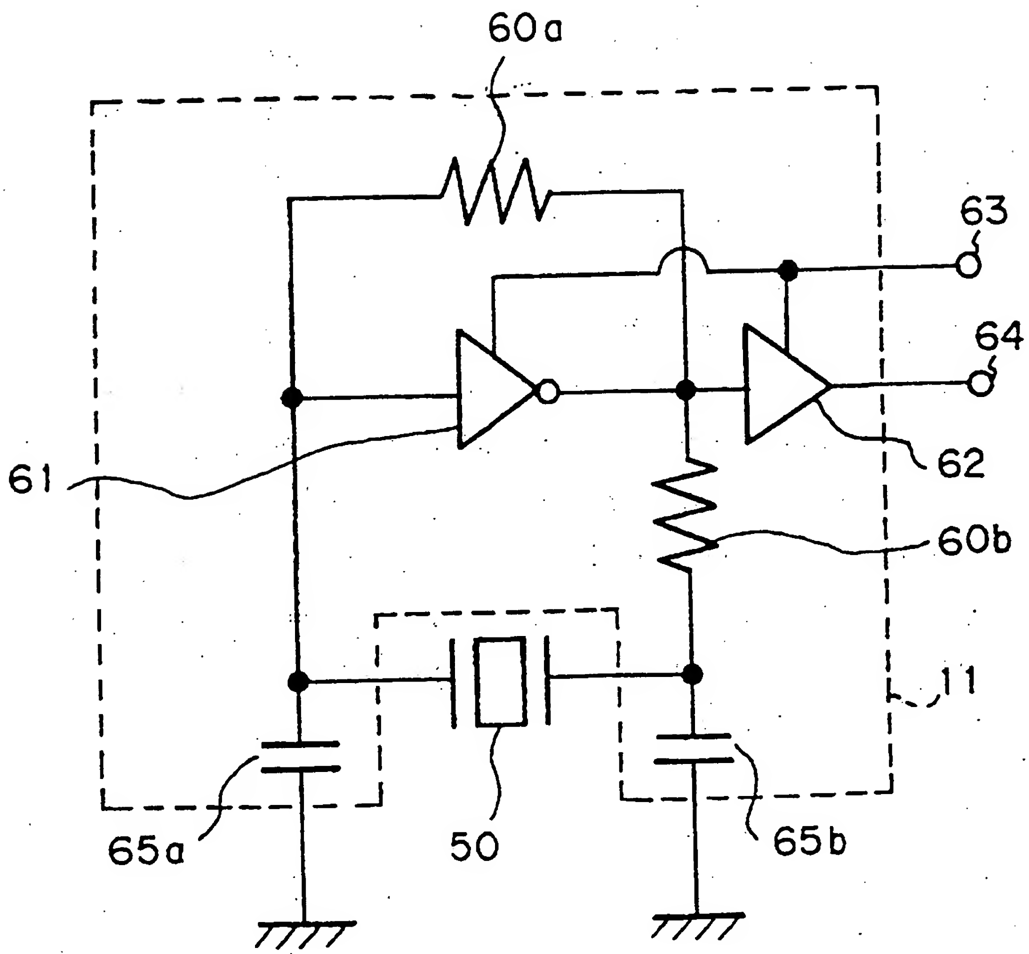


FIG. 16



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MULTICHIP MODULE

The present invention relates to a multichip module (MCM). A particular multichip module to be described below by way of example in illustration of the invention includes a semiconductor device and a surface acoustic wave (SAW) filter device mounted on a ceramic substrate.

There is an increasing demand for miniature portable apparatus, e.g. a handy phone, which is smaller in size and weight, is integrated to a higher degree, and features more advanced functions, than existing apparatus.

A previously proposed MCM which is intended to meet the above requirements has the problem that it cannot reduce the mounting area because there are a plurality of devices arranged side by side in a hermetic container. Further, the previously proposed MCM is expensive and heavy. In addition, it is difficult electrically to make connections to the various devices because they are arranged in a single space and connected together by bonding wires.

Japanese Laid-Open patent publication No. 7-153903 discloses an MCM including an MCM substrate for mounting a semiconductor chip. A frame is provided on the MCM substrate in such a manner as to surround the semiconductor chip. Sealing resin fills the gap between the frame and the semiconductor chip in order to seal the chip. Electrode terminals are arranged on the surface of the frame opposite to the MCM substrate and are electrically connected to circuitry formed on the substrate. The electrode terminals are provided by solder bumps or conductive paste. The semiconductor chip is mounted on one major surface of the MCM substrate for mounting on a motherboard. Semiconductor packages each including the above MCM substrate loaded with the semiconductor chip are stacked in order to improve

the efficient mounting of the semiconductor chips. However, the mounting efficiency achievable with this configuration is limited because an LSI (Large Scale Integrated) circuit chip is mounted on only one major surface of the MCM substrate.

Disclosures which may be relevant to the present invention are also to be found in e.g. Japanese Laid-Open Patent Publications No. 7-131129, 8-78616 and 8-153834.

Features of an MCM to be described below by way of example in illustration of the present invention are that it is capable of enhancing the efficient mounting of devices and of facilitating insulation between the devices.

A particular MCM to be described below by way of example in illustration of the present invention includes a first substrate formed with through holes and having shield electrodes arranged therein. At least one semiconductor device is mounted on one major surface of the first substrate and electrically and mechanically connected to the first substrate by a first conductive material. A second substrate is mounted on the other major surface of the first substrate and formed with through holes. At least one filter device is mounted on the other major surface of the first substrate and electrically and mechanically connected to the first substrate by a second conductive material. The second substrate is electrically connected to the semiconductor device by the through holes and first conductive material.

Reference will now be made to a previously proposed arrangement, together with arrangements which are given by way of example, and which enable the present invention to be described, in association with the accompanying drawings, in which:-

FIG. 1 is a sectional view showing a previously proposed MCM,

FIG. 2 is a top plan view of a first arrangement of an MCM illustrative

of the present invention,

FIG. 3 is a sectional view along line A-A' of FIG 2,

FIG.4 is an exploded perspective view of the first arrangement,

FIG. 5 is a perspective view showing a semiconductor device and a SAW filter device included in the first arrangement in a mounted condition,

FIG. 6 is a block schematic diagram showing the flow of signals which occur in the radio transmission/reception section of a handy phone including the first arrangement during reception,

FIG. 7 is a side elevation of the first arrangement,

FIG. 8 is a view showing a specific configuration of a SAW filter device,

FIG. is a schematic diagram for use in describing the operation of a first mixer shown in FIG. 6,

FIG. 10 is a block schematic diagram showing the flow of signals which occur in the radio transmission/reception section during transmission,

FIG. 11 is a cross-sectional view of a second arrangement illustrative of the present invention;

FIG. 12 is a block schematic diagram showing the radio transmission/reception section of a handy phone including the second arrangement,

FIG. 13 is a cross-sectional view of a third arrangement illustrative of the present invention,

FIG. 14 is a block schematic diagram showing the radio transmission/reception section of a handy phone including the third arrangement,

FIG. 15 is a sectional view showing a fourth arrangement illustrative of the present invention, and

FIG. I6 is an equivalent circuit representative of a quartz device

included in the fourth arrangement.

To enable the invention to be better understood, a brief reference will first be made to the previously proposed MCM, shown in FIG. 1. As shown, the MCM includes a semiconductor device 80 and a SAW filter device 78 mounted side by side on a ceramic substrate 70. Input/output electrodes 75 and 79 are formed on the semiconductor device 80 and the SAW filter device 78. Interdigital electrodes 77 are formed on the SAW filter device 78. External electrodes 73 are provided on the underside of the substrate 70, and each is electrically connected to one of the input/output electrodes 75 by a respective through hole 72. There are also shown in FIG. 1 a seam ring 74 providing a seam for intercepting extraneous noise between the body of the device and a metallic cover 81.

In the above previously proposed MCM, the input/output electrodes 75 and 79, the interdigital electrodes 77 and other structural elements are arranged side by side horizontally in a hermetic container. The MCM therefore occupies a comparatively large mounting area. Further, the inclusion of the seam ring 74 and the metallic cover 81 in the MCM, in addition to the above structural elements increases the cost and the weight of the MCM. In addition, it is difficult electrically to connect the various devices, because they are arranged in a single space and connected together by bonding wires as shown at 76.

Arrangements illustrative of the present invention will now be described, by way of example.

Referring to FIGS. 2-5, an MCM is shown which is shown in a receiving section of a handy phone. As shown in FIG. 4, the MCM includes a ceramic substrate 1 having an upper major surface and a lower major surface (referred to simply as an upper surface and a lower surface hereinafter). A

semiconductor device 11 and a SAW filter device 5 are respectively mounted on the upper and lower surfaces of the ceramic substrate 1. Another ceramic substrate 2 is positioned in the area of the lower surface of the ceramic substrate 1 where the SAW filter device 5 is absent. As shown in FIGS. 2 and 5, there are eight external terminals 3a-3h at the four corners of the two rectangular portions of the ceramic substrate 2 for connection to external circuitry.

The substrates 1 and 2 may be formed of a material other than ceramics, e.g. glass-epoxy resin. In the illustrative embodiment, the semiconductor device 11 and the SAW filter devices are mounted on the ceramic substrate 1. However, a feature is that at least one of a semiconductor device, a dielectric device and a SAW filter device or similar piezoelectric device should be mounted on the ceramic substrate 1. For mounting the above devices to the ceramic substrate 1, use may be made of metallic bumps, or conductive adhesive, or other similar conductive material. The metallic bumps refer to electrodes adapted for a semiconductor chip or wiring leads.

As shown in FIG. 3, in the particular embodiment, shield electrodes 8 are formed in the ceramic substrate 1. The semiconductor device 11 and the SAW filter device 5 are electrically and physically connected to the upper and lower surfaces of the substrate 1 by metallic bumps 7a and 7b, respectively. The ceramic substrate 2 is positioned in the area of the lower surface of the ceramic substrate 1 where the SAW filter device 5 is absent, as mentioned earlier. Input/output electrodes 9a, 9d, and 9e are provided on the upper and lower surfaces of the ceramic substrate 1. The external terminals 3e-3h are positioned on the lower surface of the ceramic substrate 2 for connection to external circuitry. The external terminals 3e-3h are electrically connected to the semiconductor device 1 and the SAW filter device 5 by conductive patterns 12a

and 12b provided on the two substrates 1 and 2 and via through holes 6a and 6b in the substrates 1 and 2.

Resin 10a is used to fill in the gap between the ceramic substrate 1 and the semiconductor device 11. The surface of the SAW filter device 5, where interdigital electrodes 14 are present, is covered with a protective film 13 of, e.g. SiO_2 (silicone dioxide). The gap between the ceramic substrate 1 and the portion of the SAW filter device 5 where the interdigital electrodes 14 are absent is filled by resin 10b. The interdigital electrodes 14 refer to electrodes formed on a piezoelectric or a dielectric body and arranged in the form of the teeth of two interleaved combs alternating with each other.

The ceramic substrate 1 separates the space accommodating the semiconductor device 11 from the space accommodating the SAW filter device 5. In addition, the shield electrodes 8 provide isolation from an electric field above them and an electric field below them.

The upper surface of the ceramic substrate 2 and the external terminals 3g and 3h define a distance B therebetween. Likewise, the lower surface of the SAW filter device 5 and the metallic bumps 7b and the input/output electrodes 9c and 9e define a distance A therebetween. The distance B is selected to be greater than the distance A. Should the distance A be greater than the distance B, the SAW filter device 5 would protrude from the lower surface of the ceramic substrate 2 and would abut against a surface on which the MCM is to be mounted.

The operation of the transmission/reception section of the handy phone including the above MCM will now be described. FIG. 6 shows the flow of signals that occurs in the transmission/reception section during reception. As shown, a radio signal wave is received via either one of two antennas 20a and 20b to provide a received electric signal. The electric signal output from the

antenna 20b is passed to the extemal terminal 3f included in the MCM, indicated by the numeral 25, via an antenna duplexer 30, an amplifier 22b, and a switch 24. The electric signal output from the other antenna 20a is routed through a receiving filter 21, an amplifier 22a and the switch 24 to the external terminal 3f of the MCM 25. The receiving filter 21 has a centre frequency of, e.g., 847.5 MHz.

As shown in FIG. 7 the signal applied to the extemal terminal 3f is fed to the interdigital electrodes 14 of the SAW filter device 5 by way of the associated through hole 6a, conductive pattern 12a, input/output electrode 9c of the ceramic substrate 1, bump 7b, and input/output electrode 9d of the filter device 5.

More specifically, as shown in FIG. 8, an electric signal S1 is input to the SAW filter device 5 and converted to a surface acoustic wave 40. The surface acoustic wave 40 is propagated through the interdigital electrodes 14 and again transformed to an electric signal S2. The electric signal S2 is input to the input/output electrode 9e. The SAW filter device 5 is used because it has a sharp frequency characteristic, i.e. it has good frequency selectivity. The characteristic of the output signal S2 derived from the input signal S1 is determined mainly by the design of the pattern of the interdigital electrodes 14. The SAW filter device 5 is a band-pass filter capable of passing only a preselected frequency band having a centre frequency of. e.g. 874.5 MHz.

The electric signal S2 output from the SAW filter device 5 is routed through the bump 7b, the conductive pattern 12b and the through hole 6b to the semiconductor device 11 having a mixing function. A local oscillation signal output from a first local oscillator 26a, as indicated by a dashed arrow in FIG. 6, is input to the semiconductor device 11 via an external terminal 25d also included in the MCM 25, the through hole 6a, the conductive pattern 12a, and

the bump 7a.

With reference to FIG. 9, assume that the signal received via the antenna 20a or 20b has a frequency f1, that the first local oscillator 26b has a frequency f2, and that the frequency f2 is higher than the frequency f1. Then, a first mixer 27a outputs an intermediate frequency produced by f2-f1. As a result of the so-called beating which is customary with, e.g., a super-heterodyne receiver, the first mixer 27a produces a difference between the signal output from the antenna 20a or 20b and the signal output from the first local oscillator 26a. The signal S21 output from the first local oscillator 26a has a frequency of, e.g. 717.5 MHz.

As shown in FIG. 6, the signal S2 is fed from the first mixer 27a to a second mixer 27b via a first intermediate filter 28a. The second mixer 27b produces a signal representative of a difference between the output frequency of the intermediate filter 28b and the frequency of a local oscillation signal output from a second local oscillator 26b (indicated by a dashed arrow). This signal is fed from the second mixer 27b to two second intermediate filters 28b.

The first intermediate filter 28a may have a centre frequency of 130 MHz while the second intermediate filters 28b may have a centre frequency of 450 MHz each. Also, the second local oscillator 26b may have an oscillation frequency of 129.55 MHz.

The signal passed through the second intermediate filters 28b is amplified by an amplifier 22c and then input to a modulator/demodulator (DEM) 29 using the conventional quadrature amplitude modulation scheme. Quadrature amplitude modulation modulates the amplitude of each of two carrier waves, which are different in phase by 90 degrees, with a particular digital signal and combines the resulting modulated signals. The DEM 29 outputs signals I and Q which are subjected to quadrature amplitude

modulation. The signals I and Q are respectively the in-phase component and the quadrature component of the baseband signal subjected to the above modulation.

FIG. 10 shows the flow of signals which occurs in the transmission/reception section during transmission. The transmission of a signal will be described only briefly because it is not relevant to the understanding of the arrangement being described. As shown, an AGC (Automatic Gain Control) circuit 32 amplifies a signal to be transmitted such that a preselected gain is obtainable. Specifically, the AGC 32 automatically controls the gain of an amplifier in such a manner as to produce a preselected output. The output of the AGC 32 is passed through a SAW filter device 25c to a power amplifier 31 and amplified thereby. The amplified output of the power amplifier 31 is radiated via the antenna duplexer 30 and the antenna 20b. On the transmission side, the SAW filter device has an oscillation frequency of, e.g. 942.5 MHz.

As mentioned above, in the arrangement being described, the semiconductor device 11 and the SAW filter device 5 are mounted on the opposite major surfaces of the ceramic substrate 1. This successfully improves the mounting efficiency. In addition, the external terminals 3a-3h on the ceramic substrate 2 allow the MCM to be connected to external circuitry comparatively easily.

Referring to FIG. 11 there is shown an arrangement which differs from the first arrangement described in that two semiconductor devices 11a and 11b are mounted on the ceramic substrate 1. FIG. 12 shows the radio transmission/reception section of a handy phone including an MCM representative of that shown in FIG. 11. In FIG. 12, the MCM is generally designated by the reference numeral 25. The operation of this arrangement is

identical to that of the arrangement first described and will not be repeated.

The semiconductor devices 11a and 11b mounted on the upper surface of the ceramic substrate 1 improve the efficient mounting for a modular configuration and broaden the range of modules which may be selected.

FIG. 13 shows an arrangement in which two SAW filter devices 25a and 25b are mounted on the upper surface of the ceramic substrate 1, while the semiconductor device 11 is mounted on the lower surface of the substrate 1. FIG. 14 shows the radio transmission/reception section of a handy phone including an MCM representative of the that used in the arrangement of FIG. 13. In FIG. 14, the MCM is generally designated by thc reference numeral 25.

The operation of this arrangement is substantially the same as that of the previously described arrangements.

The SAW filter devices 25a and 25b mounted on the upper surface of the ceramic substrate 1 also provide an improvement in the efficiency of the mounting for a modular configuration and broaden the range of modules from which a selection may be made.

Referring now to FIG. 15 there is shown an arrangement which differs from the first described arrangement in that a quartz device 50 is substituted for the SAW filter device 5. An oscillator using quartz has customarily been used in a handy phone as a reference oscillation frequency source. For this purpose, the oscillator is usually implemented as a temperature compensated oscillator (TCXO) because it must be highly stable. A metallic cover 55 is used in combination with the quartz device 50 in order to seal it. Specifically, the cover 55 hermetically seals the quartz device 50 in order to protect the oscillation electrodes which are on the opposite sides of the quartz device from oxidation There are also shown in FIG. 15 lead electrodes 51, input/output electrodes 52a and 52b, conductive adhesive 53, and oscillation electrodes 54.

electrodes 52a and 52b, conductive adhesive 53, and oscillation electrodes 54.

FIG. 16 shows an equivalent circuit representative of the quartz device 50. As may be seen, the semiconductor device 11 forms a part of an oscillation circuit which includes resistors 60a and 60b, an inverter 61, a buffer amplifier 62 and capacitors 65a and 65b. The oscillation circuit has a bias terminal 63 and an output terminal 64.

In summary, it will be seen that in the arrangements described there is an MCM which enables different devices to be mounted on the opposite major surfaces of a substrate, thereby improving mounting efficiency. Structural members other than the devices mounted on the MCM are reduced in size as far as possible and are therefore lighter in weight. Furthermore, the spaces above and below the substrate for mounting the devices are isolated by the substrate. As a result, shield electrodes arranged in the substrate isolate the respective electric fields which are above and below the substrate, making more easy the insulation between the devices.

It will be understood that, although particular arrangements have been described, by way of example, in illustration of the invention, variations and modifications thereof, as well as other arrangements may be made within the scope of the protection sought by the appended claims.

CLAIMS

1. A multichip module including a first substrate having through holes and shield electrodes, at least one semiconductor device mounted on one of the opposite major surfaces of the first substrate and being electrically and mechanically connected to the first substrate by a first conductive material, a second substrate having through holes and at least one filter device mounted on the other major surface of the first substrate and electrically and mechanically connected to the first substrate by a second conductive material, the second substrate being mounted on the other major surface of the first substrate and being electrically connected to the semiconductor device by the through holes and the first conductive material.

2. A multichip module as claimed in claim 1 having two semiconductor devices on the one major surface of the first substrate.

3. A multichip module as claimed in either claim 1 or claim 2 having two filter devices on the other major surface of the first substrate.

4. A multichip module as claimed in claim 3 having resin between the first substrate and the two semiconductor devices and between the first substrate and the two filter devices.

5. A multichip module as claimed in claim 4 in which the filter devices include SAW filter devices.

6. A multichip module as claimed in claim 2, having a quartz device on

the other major surface of the first substrate.

7. A multichip module as claimed in claim 1 having resin between the first substrate and the at least one semiconductor device and between the first substrate and the at least one filter device.

8. A multichip module as claimed in claim 1 in which the at least one filter device includes a SAW filter device.

9. A multichip module as claimed in claim 1 wherein the at least one filter device is a quartz device.

10. A multichip module as claimed in claim 1 including an arrangement substantially as described herein with reference to any one of Figs. 2 to 10, 11 and 12, 13 and 14, or 15 and 16 of the accompanying drawings.

The Patent Office

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INVESTOR IN PEOPLE

Application No:	GB 9912300.2	**Examiner:**	Miss E.L.Rendle
Claims searched:	1-10	**Date of search:**	4 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1K (KRF, KPJ, KPXDB, KPXMB, KPXB, KPX); H1R (RBF)

Int Cl (Ed.6): H01L 23/055, 25/04, 25/065, 25/07; H05K 1/14, 3/34

Other: EPOQUE: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP 0 708 484 A1	(HUGHES AIRCRAFT) see whole document, especially figures 1 and 4.	-
A	EP 0 540 247 A2	(IBM) see whole document, especially column 5 line 31 to column 6 line 17 and figures 1 and 13.	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.